REMARKS/ARGUMENTS

Favorable reconsideration of this application in light of the following discussion is respectfully requested.

Claims 1-12 and 14 are pending in this case.

In the outstanding Official Action, Claims 1, 2, 10/1, 10/2, 11/1, 11/2, 12, and 14 are rejected under 35 U.S.C. §102(b) as anticipated by Mayer, Jr. (U.S. Patent No. 3,604,661, hereinafter "Mayer"). Claims 1-3, 7, 10-12, and 14 are rejected under 35 U.S.C. §102(b) as anticipated by Passler (German Patent No. 43 34 164). However, Claims 4-6, 8, and 9 were objected to as being dependent on a rejected base claim, but otherwise were indicated as including allowable subject matter if re-written in independent form.

Applicants gratefully acknowledge the indication that Claims 4-6, 8, and 9 include allowable subject matter.

With regard to the rejection of Claims 1, 2, 10/1, 10/2, 11/1, 11/2, 12, and 14 as anticipated by Meyer, the rejection is respectfully traversed.

Independent Claim 1 recites an aeroplane provided with a noise-reducing unit configured to reduce a noise level produced during a flight, comprising *inter alia*,

> a blowing unit having a blowing element including at least one blowing nozzle for creating an air screen at a front side of a portion of the landing gear, said air screen configured to deflect air flow away from said portion of said landing gear to reduce said noise level.

Meyer describes a ***boundary layer control means*** including slots 17, 20, and 22 configured to discharge air along the surface of a wing or fuselage of an airplane to increase the speed of the air in the boundary layer of the wing or fuselage. The increased air speed lowers the air pressure in the boundary layer.[1]

[1]See Meyer, column 1, lines 4-16, column 2, lines 42-48, column 5, lines 6-20, and Figures 1 and 2.

Enclosed herewith is a copy of educational materials (MECH 386 - TOPIC 6) available on the website of the University of British Columbia (http://batman.mech.ubc.ca/~green/MECH386/Topic%206.htm). It is respectfully submitted that these materials reflect the knowledge of those skilled in the art regarding boundary layers. The materials state that a boundary layer is a *thin* region located near a surface in a flow.[2] The materials also include examples of boundary layer thicknesses for a Boeing 747, one of the largest airplanes available. Using the exemplary values, including a mean chord length of 8.6 m for a Boeing 747, the following boundary layer thicknesses were computed. For laminar flow, the boundary layer is only 7.5 mm, and, for turbulent flow, the boundary layer is only 116 mm (less than 5 inches!).[3] It is respectfully submitted that for smaller planes, the mean chord length will be smaller, leading to even smaller boundary layers. Thus, it is respectfully submitted that one skilled in the art would realize that a boundary layer control apparatus as disclosed by Mayer would not affect the landing gear in any way, as the landing gear extends far beyond the thickness of the boundary layer around the fuselage.

The Final Office Action stated on page 2, lines 12-15 that "This downwardly directed air from lowermost slots 22 of Mayer Jr. would serve to deflect at least a minimal amount of the oncoming flow from the landing gear of the craft by entraining it and conducting it away from the aircraft." However, it is respectfully submitted that a showing of inherency has not been met.

"To establish inherency, the extrinsic evidence 'must make clear that the missing descriptive matter is necessarily present in the thing described in the reference, ***and*** that it would be so recognized by persons of ordinary skill. Inherency, however, may not be established by probabilities or possibilities. The mere fact that a certain thing may result

[2]See MECH 386 - TOPIC 6, page 1, lines 4 and 5.
[3]See MECH 386 - TOPIC 6, pages 4 and 5.

from a given set of circumstances is not sufficient.'" *In re Robertson*, 49 USPQ2d 1949, 1950-51 (Fed. Cir. 1999) (emphasis added, citations omitted). See also MPEP §2112.

It is respectfully submitted that neither requirement stated in the above controlling case law has been met. First, no extrinsic evidence has been cited or provided supporting the assertion made in the Final Office Action. Further, as stated above, it is respectfully submitted that one skilled in the art would not only fail to realize that the apparatus described in Mayer inherently teaches the invention recited in Claim 1, but, in fact would realize the opposite. Specifically, one skilled in the art would realize that the apparatus disclosed by Mayer would not affect the air flow around the landing gear. Accordingly, it is respectfully submitted that Mayer does not teach or suggest, explicitly or inherently, "a blowing unit having a blowing element including at least one blowing nozzle for creating an air screen at a front side of a portion of the landing gear, said air screen configured to deflect air flow away from said portion of said landing gear to reduce said noise level," as recited in Claim 1.

Since Mayer does not teach, explicitly or inherently, each and every element of Claim 1, Claim 1 is not anticipated by Mayer and is patentable thereover.

With regard to the rejection of Claims 1-3, 7, 10-12, and 14 as anticipated by Passler, the rejection is respectfully traversed.

Passler describes an apparatus for blowing water off the runway in front of the tires of a plane that is landing, to prevent the tires from hydroplaning on puddles on the runway.[4] The apparatus blows air roughly horizontally at a level near the bottom of the tires of the aircraft to ensure that the tires do not go over any puddles.

With regard to the Passler reference, the Final Office Action states on page 2, line 18 to page 3, line 4 that:

> The unit is mounted to the underside of an aircraft and in advance in of the tires of an aircraft's landing gear (see

[4]See Passler, Figures 1-4.

> Figures 1, 2 of Passler) such that some of the expelled air inherently would deflect - in the nature of an air screen - ambient air away from a portion of the tires, thereby reducing the noise level. For example, air exiting the blowing unit 1 of Passler to the right and left would entrain some oncoming air, diverting it accordingly to both sides. Whether one skilled in the art would recognize the existence of this process would seem to be secondary to the fact that it does occur.

Again, it is respectfully submitted that the legal requirements for a showing of inherency have not been met. First, no extrinsic evidence has been cited or provided supporting the assertion made in the Final Office Action. Second, it is respectfully submitted that one skilled in the art would not realize that the apparatus described in Passler inherently teaches the invention recited in Claim 1. The statement in the Final Office Action that recognition of noise reduction by those skilled in the art would be secondary to the fact that noise reduction occurs is both contrary to controlling case law which requires recognition of the alleged inherent teaching by those skilled in the art, as well as lacking in any support for the allegation that noise reduction occurs.

In this last regard, the purpose of Passler, to blow water off the runway in advance of the landing gear wheels, at least suggests that the air streams produced must be forward of the landing gear or it would not be able to clear water away before the tires reached the cleared area. The distance would be dependent on many factors, but not on any desire to provide the claimed air screen to deflect air from the landing gear.

Furthermore, and as discussed in the Amendment filed July 19, 2004, one skilled in the art would not recognize that the apparatus described by Passler would form an air screen in front of a portion of the landing gear to reduce noise caused by the landing gear. It is respectfully submitted that the velocity of the air leaving this apparatus is substantially parallel to the horizontal, to ensure the water on the runway is blown away from the tires. Only a small downward component is included ensure the air flow reaches the runway. (The device cannot be placed even with the bottom of the tires, as the tires compress on landing.)

To the extent the apparatus blows air down, this is wasted energy as the downward velocity will not blow water away from the tire path. Accordingly, it is respectfully submitted that one having ordinary skill in the art would recognize that the optimal design of the device described by Passler would have the air expelled nearly horizontally, with the apparatus located just above the ground. In fact, it is respectfully submitted that one with ordinary skill would recognize that the apparatus described in Passler significantly increases the noise level of the plane as it lands.

Since Passler does not teach, explicitly or inherently, each and every element of Claim 1, Claim 1 is not anticipated by Passler and is patentable thereover.

It is respectfully noted that *Ex Parte Bonfils*, 64 USPQ2d 1456 (B. P. A. I. 2002), requires that a translation of a foreign language document be provided before forwarding an appeal to the Board of Patent Appeals and Interferences. Since a translation of Passler will be required before forwarding an appeal to the Board of Patent Appeals and Interferences, it is respectfully requested that a translation of Passler be provided to applicants with the response to the present Request for Reconsideration.

Claims 2, 3, 7, 10, and 11 are dependent from Claim 1, which applicants believe is patentable for the above stated reasons. Accordingly, Claims 2, 3, 7, 10, and 11 are also believed to be patentable at least for the reasons discussed above with respect to Claim 1.

Claims 12 and 14 recite similar elements as Claim 1. Accordingly, Claims 12 and 14 are believed to be patentable for the reasons noted above with respect to Claim 1.

Accordingly, the outstanding rejections are traversed and the pending claims are believed to be in condition for formal allowance. An early and favorable action to that effect is respectfully requested.

Respectfully submitted,

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MECH 386 – TOPIC 6

Boundary Layers, Separation, and Drag

Refresher Course on Boundary Layers

- As you have seen in MECH 380 or equivalent courses, boundary layers are *thin* regions located near a surface in a flow
- Let's denote the local coordinate parallel to the surface by x (with associated velocity component u) and the coordinate perpendicular to the surface by y (with associated velocity component v)
- We may do this even if we have a curved surface
- If we denote the local freestream velocity by U_∞ then we typically define the boundary layer thickness as the height (in the y direction) δ above the surface at which u=0.95 U_∞
- As you will recall from our discussion of the Law of the Wall, even in a turbulent flow, the laminar sublayer is a region of the flow in which velocity gradients ($\partial u/ \partial y$) are exceptionally high, and therefore laminar viscous effects are dominant
- In laminar boundary layers too ($\partial u/ \partial y$) is very large. Both laminar and turbulent boundary layers are thus regions with large velocity gradients

Q: Sketch below the velocity profile through typical laminar and turbulent boundary layers.

A:

Q: For a flat plate with no pressure gradient, do you recall how the laminar boundary layer thickness varies with distance along the plate?
A:

Q: For a flat plate with no pressure gradient, do you recall how the turbulent boundary layer thickness varies with distance along the plate?
A:

- In addition to δ, two other boundary layer thicknesses are useful:

$$\delta^* = \frac{1}{U_\infty}\int_0^\infty [U_\infty - u(y)]dy$$

where δ* is the ***displacement thickness***, and

$$\theta = \frac{1}{U_\infty^2}\int_0^\infty u(y)[U_\infty - u(y)]dy$$

where θ is the ***momentum thickness***

- The displacement thickness is the thickness of the fluid layer moving at U_∞ necessary to make up for the mass flow deficit in the boundary layer
- The momentum thickness is the thickness of the fluid layer moving at U_∞ necessary to make up for the momentum flux deficit in the boundary layer
- For a laminar flat plate boundary layer with no pressure gradient, $\delta^* \approx \delta/3$ and $\theta \approx 2\,\delta/15$
- The ***shape factor*** of a boundary layer is given by $H=\delta^*/\theta$
- For a Blasius Boundary Layer, H =2.59

Calculation of H for a Turbulent Boundary Layer

- In a flat plate turbulent boundary layer without an imposed pressure

gradient, the approximate velocity distribution through the boundary layer is given by:

$$\frac{u}{U_\infty}=\left(\frac{y}{\delta}\right)^{1/7}$$

Q: Can you evaluate H for a turbulent boundary layer?
A:

$$\theta=\int_0^\delta\left({y\over\delta}\right)^{1/7}\left[{1-\left({y\over\delta}\right)^{1/7}}\right]dy=(7/72)\delta \tag{8}$$

$${\rm Also,}\, \delta^*=\int_0^\delta\left[1-\left({y\over\delta}\right)^{1/7}\right]dy=(1/8)\delta\qquad H={\delta^*\over\theta}=1.3 \tag{9}$$

- As we have just seen, H is smaller for a turbulent boundary layer than for a laminar one
- The value of H is an indication of how prone a boundary layer is to separation
- For laminar boundary layers, if H=3.5 separation is imminent
- For turbulent boundary layers, if H=2.4 separation is imminent
- Smaller H is good in terms of avoiding separation because it implies higher transverse momentum exchange in the boundary layer
- In other words, if H is small, higher momentum fluid from further away from the wall is brought closer to the wall. This fluid has more kinetic energy and is therefore more capable of "coping with" adverse pressure gradients
- H is used in various sophisticated methods (e.g. Head's method) for computing laminar and turbulent boundary layer growth. Those methods

are beyond the scope of this course.

Transition

- All boundary layers start life as laminar boundary layers, and at some distance along the surface (this location may be very near the start of the surface), the flow ***transitions*** to turbulent
- The location of transition is a function of many variables, including the local freestream turbulence level, the pressure gradient along the surface, the surface roughness, and the local Reynolds number, Re_x
- For a rough flat plate with some turbulence in the freestream, the transition Reynolds number is about Re_x=500,000
- If the plate is very smooth and the freestream has a low turbulence level, one may delay transition to Re_x=3,000,000
- With the strongly favourable pressure gradient that occurs in a converging nozzle, for example, a previously turbulent flow may transition back to laminar, a process called ***relaminarization***

Simple Example

A Boeing 747 wing has a mean chord of 8.6 m, a wing span of 60 m, and flies at 280 m/s at an elevation of 15 000m.

1. Estimate the boundary layer thickness at the end of the wing if the flow were laminar everywhere.
2. Re-estimate this thickness if the flow were turbulent everywhere.
3. What is the approximate transition location?

SOLUTION

$$\mathrm{Re}_L = \left(\frac{280\times 8.6}{7.3\times 10^{-5}}\right) = 3.3\times 10^7$$

If the flow were laminar everywhere the boundary layer thickness would be

$$\delta = \frac{5.0\times L}{\sqrt{\mathrm{Re}_L}} = \frac{5.0\times 8.6}{\sqrt{3.3\times 10^7}} = 7.5mm$$

at the trailing edge of the wing!!

If the flow were turbulent (obviously the case for such a large Re_L), then

$$\delta = \frac{0.16\times L}{(\mathrm{Re}_L)^{1/7}} = \frac{0.16\times 8.6}{(3.3\times 10^7)^{1/7}} = 116mm$$

which is much larger than the laminar result.

If we assume transition occurs for $\mathrm{Re}_x=5\times 10^5$ then

$$x_{transition} = \frac{5\times 10^5 \times 7.30\times 10^{-5}}{280} = 0.13m$$

Transition occurs 0.13 m from the wing leading edge. Most of the wing sees turbulent flow. A huge effort is underway at aircraft companies to move back the location of transition, through (proprietary) wing shape modification

Separation

Q: What do we mean when we say that flow separates from a surface?
A:

- In two-dimensional flow, the wall shear stress drops to zero at the location of separation

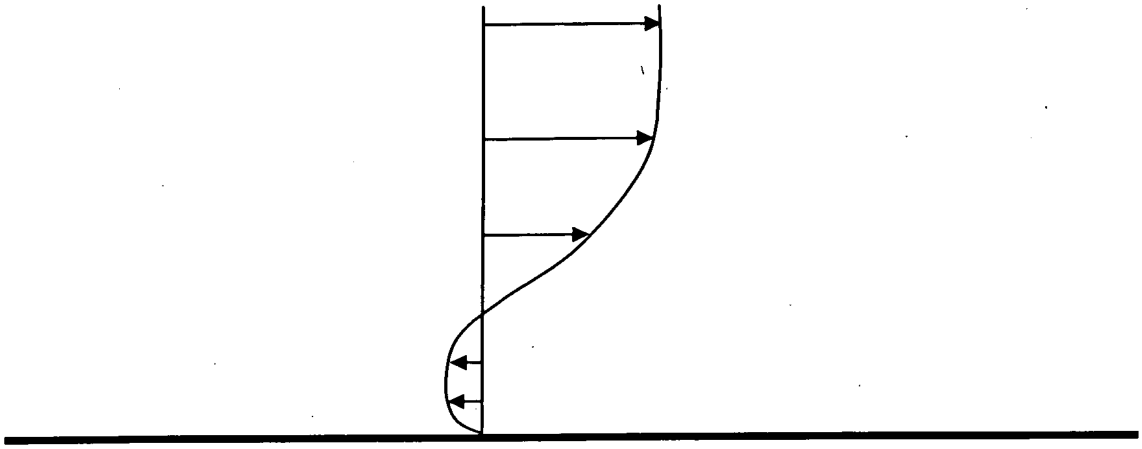
Q: Can you explain why?
A:

- At a wall in either a laminar or turbulent boundary layer, one may show easily that:

$$\left.\frac{\partial^2 u}{\partial y^2}\right|_{wall} = \frac{1}{\mu}\frac{dp}{dx}$$

Q: If one has an unfavourable or adverse pressure gradient, what is the sign of *dp/dx*?
A:
Q: In view of the above, can you sketch *u*(*y*) very near the wall?
A:

- If dp/dx is sufficiently positive (sufficiently adverse pressure gradient), then the flow separates from the wall:



- As alluded to above, one way to predict whether separation will occur is to compute the value of H along a surface.
- Thwaites' method is an example of a separation calculation procedure involving H that works quite well, but only for laminar flow
- Turbulent separation calculation procedures also exist, but are very complex and are not as reliable
- Separation is, however, very easy to see experimentally by means of dye injection or tufts:

Figure 32 of van Dyke

Figure 33 of van Dyke

Figure 38 of van Dyke

Figure 47 of van Dyke

- Separation in highly three-dimensional flow is more difficult to describe precisely. It is **not** true that the wall shear stress drops to zero in a 3D separated flow:

Figure 74 of van Dyke

Sources of Drag

- The drag in any flow can be divided into two components: ***skin friction drag*** and ***pressure drag***

Skin Friction Drag

- We understand skin friction drag intuitively. Consider two cases, a pipe flow and the flow over an airfoil:

- For both cases (and in fact, in all cases), the skin friction drag may be expressed as the component of the shear stress in the freestream direction, on the object's surface, integrated over the surface area
- The local shear stress is a function of three variables: the flow Reynolds number, the local pressure gradient, and the surface roughness

Figure 7.6 of White

- For a laminar (Blasius) boundary layer the drag coefficient is:

$$c_D = \frac{1.328}{\mathrm{Re}_L^{1/2}}$$

- Note that, just as for the Moody diagram (pipe flow), c_D is independent of plate roughness

Q: Why is this so?
A:

- Prandtl and Schlichting have developed an expression for smooth flat plate c_D in turbulent flow, valid to Re=10^9:

$$c_D = \left(\frac{0.455}{\log \mathrm{Re}_L}\right)^{2.58} - \frac{1700}{\mathrm{Re}_L}$$

Q: How do you think the skin friction drag with a favourable pressure gradient compares with that for a flat plate (for which dp/dx=0)?
A:

- Unlike for laminar flow, roughness plays a large role in turbulent flat plate drag. When Re is sufficiently high, c_D is given by:

$$c_D = \left(1.89 + 1.62 \log \frac{L}{\varepsilon}\right)^{-2.5}$$

- Don't forget that the above two expressions are only valid for flat plates parallel to a stream (zero pressure gradient)

Q: Compare the laminar and turbulent drag on a smooth flat plate at Re=500,000

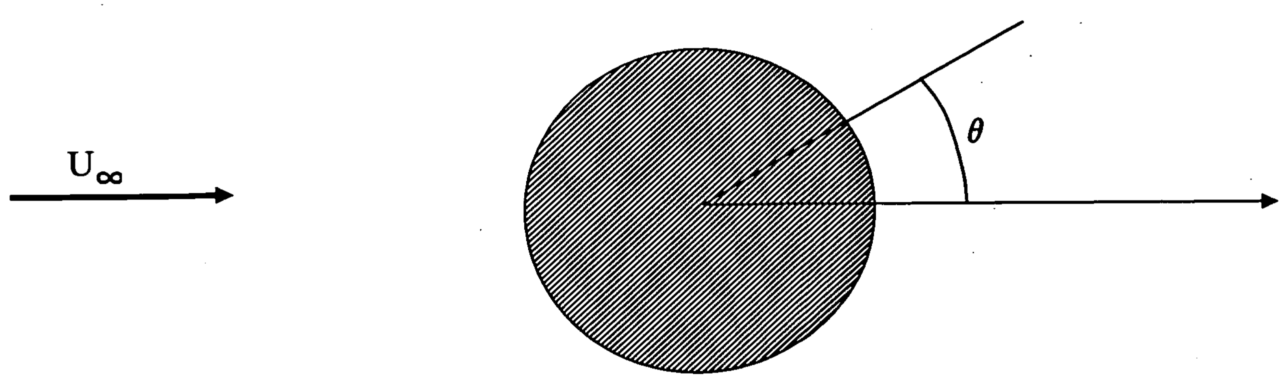
A:

- So, one way to minimize drag on a surface is to ensure that the flow remains laminar as long as possible
- Prolonged laminar flow may be attained in several ways:
  1. Reduce freestream turbulence, e.g. as produced by objects upstream
  2. Ensure a favourable pressure gradient exists (body shaping)
  3. Smooth surfaces to avoid stimulating transition

Pressure Drag

- Pressure drag is also fairly easy to understand. It is the integrated component of the pressure force, in the direction of the flow

Q: Consider a cylinder in a flow. If the pressure distribution is symmetric fore and aft, what is the pressure drag on the cylinder?



A:

Q: If the pressure at the front of the cylinder is given by: $p(\theta) = p_\infty + \frac{1}{2}\rho U_\infty^2\left(1 - 4\sin^2\theta\right)$, and for $|\theta| < 90°$ it is $0.5p_\infty$, find the pressure drag on the cylinder.

A:

- The low pressure on the back side of the cylinder is referred to as the ***base pressure***
- It is this low pressure that is the primary source of pressure drag
- For bluff bodies, where the region of flow separation is large, the pressure drag can be an order of magnitude or more larger than the skin friction drag
- For this reason, reducing the drag on a bluff body is all about reducing the pressure drag
- We can theoretically reduce the pressure drag in two ways – by increasing the base pressure and by reducing the size of the region exposed to the low base pressure
- In practice, we are largely constrained to just dealing with the latter – reducing the size of the separated flow region
- There are no hard and fast rules to guide us on changing separation
- One thing we try to avoid is having hard edges in the wake of a body, as these will almost certainly define the limits of a separated flow region
- A second thing we try to avoid is having shapes that bend away from the freestream direction too rapidly. The diffusers we studied last topic were a good example – you want to keep diffuser angles to less than about 10 degrees

- We have seen earlier that turbulent boundary layers are more resistant to separation than laminar boundary layers. For this reason, with bluff body flow, it is often desirable to transition
- For example, golf balls have their dimples because the dimples promote transition to a turbulent boundary layer, which otherwise would not occur until a much higher Reynolds number
- The turbulent boundary layer can better withstand the adverse pressure gradient on the back half of a sphere in a flow, and thus the size of the separated flow region is reduced:

Figure 55 of van Dyke

Figure 57 of van Dyke

- Owing to the complexity of predicting when separation will occur, experimentation is the only way to know we have been successful in reducing pressure drag

- The experiments might look directly at the drag, or might visualize separation, as in the photos above